

patient, it seems appropriate empirically to start antimicrobial therapy if the patient's sputum increases in amount, becomes thicker or turns yellow-green. However, if there is no satisfactory response in 48 to 72 hours, a sputum wet-mount examination is indicated. The patient may have a respiratory infection and the antimicrobial agent selected may not have affected the causative organism. It can also be determined if the increased sputum difficulty is not related to an infection but, in fact, is a manifestation of allergy.

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### Weaning Criteria for Patients on Mechanical Respiratory Assistance

IN ORDER to understand the criteria that commonly are used to determine whether patients are ready for weaning from mechanical ventilation, it is necessary to review some of the physiologic changes that may occur in those who are successfully weaned. During the first day off a ventilator there is usually a 50 percent rise in vital capacity, the tidal volume increases by about 1 ml per kg of body weight and the patient's spontaneous maximum inspiratory force increases by 6 cm of water. There is little change in the lung compliance, functional residual capacity or dead space-to-tidal volume ratio ( $V_D/V_T$ ). Invariably, there is a transient rise in the arterial carbon dioxide pressure. A small rapidly developing increase in right-to-left shunt occurs, which is reflected in a widening of the alveolar-to-arterial oxygen tension difference ( $A-a D_{O_2}$ ). In some patients there is a rise in the cardiac output; in others it falls. Significant changes in pulse and blood pressure are rarely seen. Most patients also experience some degree of sympatho-adrenal stimulation.

Many of the commonly used criteria are good predictors of successful weaning because they reflect the magnitude of these physiologic changes. The patient's underlying disease, which led to respiratory failure and mechanical ventilatory support, influences which criteria may be helpful in predicting that the time for weaning has arrived.

In general, the criteria for discontinuance are the reverse of the criteria for beginning mechanical ventilatory assistance. In patients with neuromuscular disease, a vital capacity of at least 10 ml per kg of body weight, or in adults at least 1.0 liter, and a maximum inspiratory force of at least

—20 cm of water are desirable. In the acute hypoxic states—such as noncardiogenic pulmonary edema, aspiration pneumonia or fat embolism—a system compliance of at least 30 ml per cm of water, and  $\Delta A-a_{O_2}$  of less than 200 mm of mercury (fraction of inspired oxygen, 1.0) or an arterial oxygen pressure-to-fraction of inspired oxygen ratio of at least 200 are desirable. In patients with obstructive airways the fraction of inspired oxygen, a spontaneous minute ventilation of less than 10 liters per minute, which can be doubled with effort, and a maximum inspiratory force of at least —20 cm of water probably indicate that weaning can commence. During spontaneous breathing the arterial carbon dioxide pressure should not rise faster than 2.0 mm of mercury per minute. In most instances of respiratory failure, the recovering  $V_D/V_T$  should usually be less than 0.6. Observation of vital signs after discontinuance of mechanical assistance is also important. The heart rate should not exceed about 120 per minute and the mean arterial blood pressure should not rise by more than 15 mm of mercury. No worsening of cardiac arrhythmia should occur. Greatly increased metabolic rates, as seen in patients with high fever, or abnormalities of electrolytes may also make weaning difficult.

It should be stressed that none of these criteria are absolute predictors. It is not easy to accurately assess diaphragm function, metabolic work and cardiac function at the bedside. Therefore, these criteria are guidelines. They should alert a physician to the likelihood of success or failure in weaning a patient but they should not necessarily deter initiating an attempt to restore patient support of respiration.

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### Biofeedback in Pulmonary Diseases

DYSPNEA, carbon dioxide retention and persistent dry cough are problems in pulmonary management particularly suited to ancillary therapy with biofeedback. In each instance, patients' own instinctive adaptive responses—work harder to breathe, breathe faster and really try to force out the irritant—only serve to aggravate and perpetu-

ate the problem. To gain lasting improvement, patients' maladaptive behavior must be corrected; such is not possible by pharmacologic means alone. The patient must be shown what he is doing incorrectly, and the change necessary to gain the desired benefits. This training must be conducted on a regular repetitive basis with expert coaching appropriate to the occasion.

To keep costs down and availability high we rely mainly upon standard hospital equipment. The "workhorse" is the spirometer with carbon dioxide absorber and recirculating fan and enough extra oxygen to last 15 minutes. The patient is positioned so that he can see his own tracing and a base line obtained. While watching his tracing, he is urged to change his performance in the desired direction. We also employ galvanic skin resistance meters for tension reduction and electromyogram equipment for muscle education in parallel sessions. Peak flow meters and self auscultation are used to teach early detection of bronchospasm and more effective assumption of preventive measures. Since respiratory control is a varying amalgam of voluntary and autonomic control, we show the overpressures generated during coughing and subsequent reduction in flow rates to the patient. He is shown how to phonate continuously during cough, to prevent this overpressure. We follow with use of a 3 cm (water pressure) expiratory valve to slow respirations, increase tidal volumes and promote opening of collapsed airways. Early identification of the *anti-therapy* patient, who will require an entirely different approach, is an additional derivative of this methodology.

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## Value of Lung Scanning in Evaluating the Risk of Thoractomy

EQUAL IN IMPORTANCE to determining whether a lung lesion is resectable is whether or not the patient can survive the operation. To completely resect a malignant lesion of the lung but have the patient die in respiratory failure in the immediate postoperative period or be left a severe respiratory cripple is not acceptable.

A patient's ability to tolerate removal of a lung has been evaluated by such techniques as having the patient walk down the corridor with the physician, walk up stairs, or blow out a match.

Recognizing that these are only rough guides to a patient's total respiratory function, more sophisticated methods for determining how much lung function would remain following a resection were developed. These included bronchspirometry and the determination of pulmonary artery pressure after occlusion of the pulmonary artery to the lung to be resected. Recently, it was shown that selective lung function can be determined *noninvasively* and relatively simply with the use of radioisotope lung scanning.

With the use of xenon 133 or technetium 99m, quantitative perfusion lung scans can be done which allow for estimates of the expected loss of function that would result from the anticipated resection of lung tissue. For example, the postoperative forced expiratory volume in one second (FEV<sub>1</sub>) is predicted by multiplying the preoperative FEV<sub>1</sub> by the fraction of function that is found in the lung that is to remain after resection. Elective resection is inadvisable if the predicted postoperative FEV<sub>1</sub> is less than 0.8 liters, particularly without further studies such as balloon occlusion of the pulmonary artery to the lung to be resected.

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## Evaluation of Small Airways Function

SMALL AIRWAYS of 2 mm in diameter or less constitute the largest total volume of conducting airways in the lung yet direct measurement of these structures is not yet routinely possible. However, several simple and not so simple tests are available which give good indirect evidence of a critical portion of the lung that Dr. Jere Mead of Harvard has called the "silent zone." It has long been appreciated by clinicians that malfunction leading to obstruction of airflow begins and progresses significantly before development of symptoms or abnormalities on conventional spirometry. A general nihilism toward pulmonary testing developed among clinicians over the years because tardiness of diagnosis led to advanced disease unresponsive to therapy, even when acted upon promptly after diagnosis.

When usual spirometric values show airways obstruction, the search for small airways disease (SAD) is redundant, even wasteful. Detection of SAD is the prerequisite to early detection of re-